Supporting Information

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SI Text

S.1 Data. ***S.1.1. Unit of observation.*** We draw a random sample of 20,000 land plots in Costa Rica that were forested in 1960. Each plot has an area of 3 ha (minimum mappable unit). The total forest cover in Costa Rica in 1960 is 30,357 sq km. Therefore, the dataset includes approximately one plot per 1.5 sq km of forest cover. We exclude units from indigenous reserves and wetlands because they are subject to different legal and land use regimes. We also exclude the following units from the sample: 804 plots that were located in areas where GIS specialists suspected that incorrect forest cover classification may have occurred; 879 plots that were located in areas covered with clouds or shadows in Landsat images; and 59 plots that did not align well with district areas because of errors in GIS programming. The final dataset comprises 15,283 land plots. To check the accuracy of the random sampling process, we confirmed that there were no significant differences between our sample of land plots and the population (entire land area) in terms of important characteristics (forest cover change, protected status, type of protection, and proportion under each land capacity class).

S.1.2 Outcome. For the pre-1979 cohort, the outcome variable is the change in forest cover between 1960 and 1997. For the post-1981 cohort, the outcome variable is forest cover change between 1986 and 1997. Forest cover across the country is measured from a combination of aerial photographs acquired between 1955 and 1960 (called the 1960 dataset) and from 1997 Landsat Thematic Mapper satellite images (Landsat data also exist for 1986, 2000, and 2005). Since our unit of observation is the minimum mappable unit, the outcome variable is binary: a plot is either forested or deforested (deforested <80% canopy cover). Although forest cover data are available for 2000 and 2005, we do not analyze the effect of protection after 1997. We impose this restriction to avoid potential bias from the effects of Costa Rica's payments for environmental services program (El Programa de Pagos de Servicios Ambientales, PSA). The PSA program started in 1997, and was mainly implemented in unprotected lands. For a post-1997 analysis, these PSA areas may not be suitable counterfactuals for protected areas. However, if we were to do a post-1997 analysis, we would be unable to exclude PSA lands from our analysis, because the geographic boundaries for these areas are not available in GIS. Therefore, we restrict our analysis to the effects of protected areas before 1997.

S.1.3 Treatment. The treatments are described in the text, as is the justification for using two cohorts. Note that the use of cohorts is fundamentally another way in which we attempt to reduce the possibility of hidden bias confounding our results (bias that arises from baselines that do not fully capture all differences among forested parcels). The use of cohorts and different years for the 'baseline' forest reduces the potential bias that arises from protection taking place over time. To make it more likely that two parcels have equivalent deforestation probabilities in the absence of protection, one would ideally want relevant covariate data, including baseline forest cover, at the very instant protection is granted to one of the parcels. The farther in time from the baseline measurement that protection takes place, the more scope there is for unobservable differences in the probability of deforestation. The potential bias from using a baseline that occurs years before the treatment assignment (i.e., most of our sample) is that protected parcels may be unobservably less likely to be deforested than their matched controls. Splitting our sample into two cohorts reduces this potential hidden bias, but does not eliminate it.

Grouping protected areas into two cohorts also has two other advantages: (1) for the 42 protected areas established before 1979, we allow more than fifteen years for a treatment effect to be observed; and (2) accounts for changes in the underlying selection process in the 1980s (for example, because of greater environmental awareness, scientific information, the initiation of eco-tourism as a concept, and the donor-imposed structural adjustment process on the government budget).

The total dataset of 15,283 plots include 2711 protected plots from pre-1979 protected areas. These areas comprise Biological Reserves (Cordillera Volcanica Central, Golfo Dulce, Grecia, Los Santos, Rio Macho, Taboga), National Monuments (Guayabo), National Parks (Barra Honda, Braulio Carrillo, Cahuita, Chirripo, Corcovado, Juan Castro Blanco, Palo Verde, Rincon De La Vieja, Santa Rosa, Tortuguero, Volcan Iraza, Volcan Poas, Volcan Tenorio, Volcan Turrialba), Protected Zones (Arenal-Monterverde, Caraigres, Cerro Atenas, Cerros de Escazu, Ceros de la Carpintera, El Rodeo, Miravalles, Rio Grande, Tenorio) and Wildlife Refuges (Corredor Fronterizo). The data include 2,022 plots from 1981–1996 protected areas. These areas comprise Biological Reserves (Cerro las Vueltas, Lomas de Barbudal), Forest Reserves (Rio Pacuare), National Parks (Arenal, Barbilla, Carara, Guanacaste, Parque Internacional la Amistad, Piedras Blancas), Protected Zones (Acuiferos Guacimo y Pococi, Cerro Narra, Cerros de Turrubares, Cuenca del Rio Banano, Cuenca del Rio Siquirres, Cuenca Rio Abangares, Cuenca Rio Tuis, El Chayote, La Selva, Las Tablas, Montes de Oro, Nosara, Peninsula de Nicoya, Rio Navarro y Rio Sombrero, Rio Toro, Tivives, Tortuguero), and Wildlife Refuges (Aguabuena, Bahia Cano Negro, Junquillal, Barra del Colorado, Bosque Alegre, Bosque Nacional Diria, Camaronal, Fernando Castro Cervantes, Gandoca-Manzanillo, Golfito, Hacienda Copano, La Marta, Limoncito, Mata Redonda, Penas Blancas, Rancho La Merced). Nine protected areas established before 1979 are not represented in our sample: five are islands that are not covered by the 1960 forest cover layer, and four are small protected areas that were not captured by the random sampling process because they are small. The latter four include two small forest reserves (Pacuare-Matina, Zona de Emergencia Volcan Arenal), the smallest national park (Manuel Antonio), and a small protected zone around Rio Tiribi.

S.1.4 Covariates. As noted in the main text, we divide our covariates into two sets. See Table S16 for summary statistics. Our core set comprises variables consistently found to causally affect deforestation in the literature (1): distance to roads, distance to forest edge, distance to nearest major city, and land use capacity classes that are based on exogenous factors. The core set of covariates comprises the following variables:

- *Distance to roads*: Roads make forests more accessible to deforestation agents, and ease the transportation of agricultural produce or logs from cleared land (2-4). We measure the distance from each plot to a road in 1969 (to a road in 1991 for the post-1981 cohort).
- *Distance to the forest edge:* Proximity to forest edges increases accessibility and the likelihood of deforestation (5, 6). We measure the distance between a land plot and the nearest cleared plot from the 1960 forest cover map (from the 1986 map for the post-1981 cohort).
- *Land use capacity*: Mild slopes, fertile soils, and humid life zones make deforestation more likely (2, 3, 5–7). We use Costa

Rica's *land use capacity classes*, which are determined by slope, soil characteristics, life zones, risk of flooding, dry period, fog, and wind influences. The classes are defined in Table S16. In the paper, we define classes I-III as "high productivity land," class IV as "medium productivity land," classes V-VII as "medium-low productivity land," and classes XIII and IX as "low productivity land" (the last is the omitted category).

- *Distance to nearest major city*: Proximity to agricultural markets is a key explanatory variable in deforestation (1, 8). Therefore, we include a measure of distance to the closest city of three major cities: Limon, Puntarenas, and San Jose.

The extended covariate set adds variables whose causal effects are less agreed upon: distance to railroads and rivers, population density, proportion of immigrants, educational levels, poverty and size of the administrative district.

- *Distance to railroads and river transportation network*. For the analysis of treatment effects from pre-1979 protection, we include a measure of the distance from each plot to a railroad (1969) or a river that is part of the river transportation network (1969). Railways and rivers may have affected accessibility of forests for deforestation and facilitated the transport of forest products before 1979 (whereas roads were most important post-1981).
- *District-level population density*: Harrison (9) finds strong correlations in Costa Rica between the population density in a canton and the level of deforestation, and this correlation has been confirmed in other studies for smaller land areas in Costa Rica (5, 6). As with all of the measures below, we measure population density at district-level (*distrito*) from the 1973 census (a mid-point in the main period of protection activity) for the analysis of pre-1979 protection effects. For the analysis of the effects of post-1981 protection, we measure the population density, proportion of immigrants, proportion of adults with secondary level education, and proportion of households using fuel-wood from the 1984 census. Geographic boundaries for the 437 districts in 2000 are defined in a GIS data layer. The number of districts increased between 1973 and 2000 because some districts were split up to form smaller districts. We use information on district splits over time (10) to re-aggregate new districts to their 1973 parent districts. In a few cases, a new district is created from more than one parent district, in which case we re-aggregate the new district and all parent districts into one unit. The final dataset therefore has 398 districts.
- *District-level proportion of immigrants*: Harrison (9) and Rosero-Bixby and Palloni (5) find correlations between the percentage of immigrants and the level of deforestation.
- *District-level proportion of adults educated beyond the secondary level*: Education increases opportunities for off-farm employment, which can reduce deforestation pressure.
- *District-level proportion of households using fuel-wood for cooking*: Fuel-wood use is a proxy for the use of forest resources by district residents, which would affect deforestation.
- *Size (area) of district*: District area is negatively correlated with administrative capacity and economic growth, which might influence deforestation and protected area placement.

As explained in the main text, we confirm the narrative and empirical evidence that these variables also affect the designation of protected areas by modeling the selection process directly using our data and a probit model (regressing a dummy variable for protection on the covariates).

S.2 Methods. ***S.2.1 Matching methods.*** In statistical jargon, avoided deforestation from protected areas is the Average Treatment Effect on the Treated (ATT). The methods of matching provide one way to estimate the ATT when protection is influenced by observable characteristics and the analyst wishes to make as few parametric assumptions as possible about the underlying structural model that relates protection to deforestation. Matching works by, *ex post*, identifying a comparison group that is "very similar" to the treatment group with only one key difference: the comparison group did not participate in the program of interest (11–13). Matching mimics random assignment through the *ex post* construction of a control group. If the researcher can select observable characteristics so that any two land units with the same value for these characteristics will display homogenous responses to the treatment (i.e., protection is independent of forest cover change for similar land units), then the treatment effect can be measured without bias. Mathematically, the key assumption is: $E[Y(0) \mid X,T = 1] = E[Y(0) \mid X,T = 0] = E[Y(0) \mid X]$ and $E[Y(1) \mid X,T = 1] = E[Y(1) \mid X,T = 0] = E[Y(1) \mid X]$, where $Y_i(1)$ is the deforestation when land plot i is protected (Y = 1 if plot is deforested), $Y_i(0)$ is the deforestation when land plot i is unprotected, T is treatment (T = 1 if protected), and X is the set of pretreatment characteristics on which units are matched. This is called the conditional independence assumption. For identification purposes, we also need one other assumption: $c < P(T = 1 \mid X = x) < 1 - c$ for $c > 0$. In other words, if all land units with a given vector of covariates were protected, there would be no observations on similar unprotected land units.

As noted in the main text (Methods), we tried a variety of matching methods and selected the one that gave us the best covariate balance (14): covariate matching that uses the Mahalanobis distance metric to identify matches that are similar to the protected plots. We match with and without calipers (see Methods in main text). Matching was done in R (15).

Table S10 presents the covariate balancing results for the pre-1979 cohort. The table is identical to Table 1 in the main text with the addition of the mean and maximum difference in the between the two empirical quantile functions (values greater than 0 indicate deviations between the groups in some part of the empirical distribution), as well as presenting the mean difference in the empirical cumulative distribution (to compare relative balance across the covariate dimensions). Although not presented here for space considerations, we also examined visually the quantile-quantile plots that plot the quantiles of a covariate of the protected parcels against that of the unprotected parcels in a square plot.

Table S11 presents the covariate balancing results for the pre-1979 cohort using calipers. Table S9 presents the covariate balancing results for the post-1981 cohort. Table S15 presents the covariate balancing results for the post-1981 cohort using calipers. As can be seen from the tables, matching substantially improves the covariate balance on all covariates. Another metric of balance comes from Cochran (16), who suggests that if balance differs by more than a quarter of a standard deviation of the relevant covariate, better balance is needed. For most of the covariates, the differences between protected and unprotected plots are more than a quarter of a standard deviation before matching in both cohorts. For all of the covariates, the differences are less than a quarter of a standard deviation. Tables S1–S4 present the covariate balancing results for both cohorts using the extended covariate set and we observe similar patterns to those using the core set.

S.2.2 Sensitivity to Hidden Bias. To determine how strongly an unmeasured confounding variable must affect selection into the treatment to undermine our conclusions, we use the bounds recommended by Rosenbaum (17). Although there are other sensitivity tests available (e.g., 18), Rosenbaum's bounds are relatively free of parametric assumptions and provide a single, easily interpretable measure of the way in which the unobservable covariate enters.

If the probability of agent j selecting into the treatment is π_j, the odds are then $\pi_j/(1 - \pi_j)$. The log odds can be modeled as a generalized function of a vector of controls x_j and a linear unobserved term, so $\log(\pi_j/(1 - \pi_j)) = \kappa(x_j) + \gamma u_j$, where u_j is an unobserved covariate scaled so that $0 \leq u_j \leq 1$. Take a set of paired observations where one of each pair was treated and one was not, and identical observable covariates within pairs. In a randomized experiment or in a study free of bias, $\gamma = 0$. Thus under the null hypothesis of no treatment effect, the probability that the treated outcome is higher equals 0.5. The possibility that u_j is correlated with the outcome means that the mean difference between treated and control units may contain bias.

The odds ratio between unit j which receives the treatment and the matched control outcome k is: $(\pi_j(1 - \pi_k))/(\pi_k(1 - \pi_j)) = \exp\{\gamma(u_j - u_k)\}$. Because of the bounds on u_j, a given value of γ constrains the degree to which the difference between selection probabilities can be a result of hidden bias. Defining $\Gamma = e^{\gamma}$, setting $\gamma = 0$ and $\Gamma = 1$ implies that no hidden bias exists, and hence is equivalent to the conditional independence assumption underlying the matching method analysis. Increasing values of Γ imply an increasingly important role for unobservables in the selection decision. The differences in outcomes between the treatment and control are calculated. We contrast outcomes using matched plots from the analysis with and without calipers. A McNemar test is then used to test the difference between the paired proportions.

Rosenbaum bounds compute bounds on the significance level of the matching estimate as $\Gamma = e^{\gamma}$ changes values. The intuitive interpretation of the statistic for different levels of Γ is that matched plots may differ in their odds of being protected by a factor of Γ as a result of hidden bias. The higher the level of Γ to which the difference remains significantly different from zero, the stronger the relationship is between treatment and differences in deforestation. A study is considered highly sensitive to hidden bias if the conclusions change for $\Gamma = e^{\gamma}$ just barely larger than 1, and insensitive if the conclusions change only for large values of $\Gamma = e^{\gamma} > 1$ (17). Note that the assumed unobserved covariate is a strong confounder: one that not only affects selection but also determines whether deforestation is more likely for the treatment units or their matched controls. Showing that a result is sensitive to a given level of hidden bias does not mean that such bias exists and that protection has no impact. Instead, the test indicates that the confidence interval for the estimated impact would include zero *if* an unobserved covariate caused the odds ratio of protection assignment to differ between the protected and matched unprotected plots to differ by Γ. If Γ is small, one should be cautious about interpreting the results.

To estimate lower bounds on the confidence intervals as Γ increases, we assume additive treatment effects and we use kernel matching with propensity scores (19) rather than covariate matching, so that the difference in the outcomes of the matched pairs is continuous. We calculate Rosenbaum bounds using the Wilcoxon test statistic, which can then be used to calculate confidence intervals as Γ increases (20, 21). Note that kernel matching yields poorer covariate balancing than the covariate matching with the Mahalanobis metric in ways that would likely bias the estimate upwards in absolute value. Indeed the kernel matching point estimates are higher in absolute value than the Table 2 matching estimates. Thus we believe the lower bounds calculated in Table 3 and Table S6 should be considered a maximum (in absolute value) in light of the estimates we generated in Table 2 and Table S5.

S.3. Supporting Analyses. ***S.3.1 Baseline reference estimate.*** The final row in Table 2 represents an estimate derived from a baseline reference, which is the most commonly suggested way of measuring avoided deforestation in climate change negotiations. This method models past deforestation as a function of observable covariates, estimated with regression methods. The estimated model is then used to predict future deforestation. We draw a new random sample of 20,000 pixels (with and without forest cover) and estimate a probit equation of deforestation for the period before 1960 using our core covariate set. Because we have no digitized observations of forest cover before 1960, we make the assumption that all of our pixels were previously forested at some point in the past. The estimated equation is then used to predict the expected deforestation probability for each parcel still forested in 1960 during the period 1960 to 1997. The difference between the predicted and the actual deforestation rates for protected plots is the estimated avoided deforestation from protection. The same procedure is conducted for parcels still forested in 1986 (i.e., observed deforestation patterns from 1960 to 1986 are used to predict deforestation in the period 1986–1997).

S.3.2 Adjusted sample estimate. Given that post-1981 protection led to avoided deforestation (see second column of Table 2), we exclude all plots protected after 1981 from the sample in the pre-1979 cohort analysis. Leaving them in the sample as potential control plots could bias the estimate down because these plots received treatment later during the estimation period. If we were to include them in our analysis, our estimated treatment effect without calipers is -0.045 and with calipers it is -0.056. This smaller estimate is consistent with our finding that protection after 1981 reduced deforestation (i.e., using post-1981 protected plots as controls for pre-1979 protection can bias the estimate toward zero). However, plot characteristics are spatially correlated and thus some of the decline in the estimate could also reflect better match quality (better covariate balancing). In other words, post-1981 protected plots are better matches for pre-1979 plots in comparison to plots that were never protected before 1997 (i.e., the latter are more likely to have been deforested and thus our estimate in Table 2 is biased upwards). The covariate balance is slightly worse for the pre-1979 matching analyses when we exclude the post-1981 protected plots as potential controls, but not substantially so.

As a robustness check, and to demonstrate how one might address a situation in which balancing becomes substantially worse when the analyst excludes plots that received treatment at later dates, we propose an alternative approach that directly adjusts the sample to incorporate the treatment effects from post-1981 protection. We use the post-1981 avoided deforestation estimate of 5.26% after matching with calipers in Table 2 (the estimate after matching without calipers was not significant, and thus would not be appropriate to use). In our sample, this percentage corresponds to 106 plots in the post-1981 protected area cohort. We thus randomly select 106 plots that were protected between 1981 and 1996, and were not deforested within that period, and we change their status from “forest” to “deforested” in 1997. We then estimate the treatment effect of pre-1979 protection, including all plots protected between 1981 and 1996 in the pool of potential matched control plots. The estimates from this adjusted analysis are -0.073 for the matching without calipers, and -0.083 for the matching with calipers. Using the extended set of covariates, the estimates from the adjusted analysis are -0.067 for the matching without calipers, and -0.101 for the matching with calipers.

S.3.3 Postmatching regressions. As noted by Ho *et al.* (14), successful matching makes treatment effect estimates less dependent on the specific postmatching statistical model. A postmatching regression can adjust for any small remaining imbalances in the matched sample. We thus also run postmatching regressions on each matched dataset from Table 2 to show that our avoided deforestation estimates are robust to alternative model specifications. We report only the marginal effect estimates because hypothesis testing is not the purpose of this analysis.

The results are presented in Table S12. The postmatching regression estimates in the first two rows of Table S12 correspond to a matching estimate in the first two rows of Table 2 in the main paper. For example, in the first column and first row of Table S12, we run a weighted Probit model of deforestation on the core set of covariates using the matched dataset from the matching procedure in the first column and first row of Table 2. The estimates presented are marginal effects calculated at the covariate means. For the matched dataset from the post-1981 cohort, we are unable to run a suitable Probit model because of a large number of completely determined failures. As an alternative, we run a weighted Linear Probability Model. The post-matching regression estimates in the first two rows in Table S12 are very similar to the matching estimates in Table 2 (difference of less than half a percentage point in all estimates). To test model dependence further (14), we ran regressions using a variety of specifications from the extended covariate set (i.e., we match on the core set and regress on elements of the extended set of variables). In the third and fourth column of Table S12, we report the regression using the full extended set because the estimates from this regression were the most different from those in Table 2. We find that the avoided deforestation estimates continue to differ little from those in Table 2.

S.3.4 Extended covariate set analysis. We estimate avoided deforestation using the extended covariate set. The covariate balancing results for the pre-1979 cohort are presented in Table S1 (without calipers) and Table S2 (with calipers). The covariate balancing results for the post-1981 cohort are presented in Table S3 (without calipers) and Table S4 (with calipers). Matching with the extended covariate set shows worse balance than for the core covariate set and these imbalances are in the direction one would expect to bias the analysis in favor of finding avoided deforestation. The estimates from the extended covariate analysis are presented in Table S5 and are similar to those in Table 2 despite the poorer quality of covariate balance.

We test the sensitivity of the caliper estimates in Table S5 to a potential unmeasured confounding variable. This test, described in Section S.2.2 above, is same as the sensitivity test for the core covariate set (Table 3). The results of this test, presented in Table S6, are not qualitatively different from the sensitivity test results for the core covariate set. The columns in the upper half of Table S6 indicate that the estimates in the first row of Table S5 remain significantly different from zero even in the presence of moderate unobserved bias. If an unobserved covariate caused the odds ratio of protection to differ between protected and unprotected plots by a factor of as much as 2.5, the 99% confidence interval would still exclude zero.

As with the core covariate set, we use the same test to examine the degree to which unobserved bias causes us to *underestimate* the effect of protection. We construct 99% confidence intervals for the estimate under varying degrees of unobserved bias. The results are presented in the lower half of Table S6. Even if an unobserved covariate causes the odds ratio of protection to differ between protected and unprotected plots by a factor of 3.5, the 99% confidence interval would still exclude conventional estimates from lower panel of Table S5.

S.3.5 Spatial Spillover Analysis. We begin by defining the treatment group as unprotected plots that are within two kilometers of the boundary of protected areas created before 1979. We define the control group as unprotected plots that are more than two kilometers away from the protected areas. For the analysis of spatial spillovers from pre-1979 protected areas, we attempt to avoid estimation bias due to spillovers from post-1981 protected areas by estimating spatial spillovers within the 1960–1986 period, instead of the 1960–1997 period that we used to estimate the direct effects of protection. For the latter analysis, we are able to identify and exclude control units that could have been affected by post-1981 protection. However, for the spillover analysis, we have no way of defining the extent of potential spillovers from post-1981 protection. Therefore, we use the earliest available measure of deforestation after 1981 as the outcome for this analysis: the change in forest cover between 1960 and 1986.

The estimates of spatial spillover effects are presented in Table S13. A negative treatment effect implies plots near protected areas experience *less* deforestation (i.e., protection has a protective effect outside the protected area). The results using matching methods (first two rows) are described in the main text. In contrast to the matching methods, the conventional method's estimate that does not control for observable differences among unprotected plots near and far from protected areas (third row of Table S13) indicates significant positive spillover effects. This estimate implies that 17% of the plots within 2 km of protected areas established before 1979 experienced would have been deforested by 1986 had they not been located near protected areas.

In the second column, we test for spillover effects on deforestation between 1986 and 1997, defining treatment as location within 2 km of protected areas created between 1981 and 1996. The results using matching methods are described in the main text.

For both time periods, we also test for spillovers in subsequent intervals (2–4 km, 4–6 km, 6–8 km). We do not find treatment effects that are significantly different from zero at the 1% level.

We also use the extended set of covariates to test for spillovers for both 1960–1986 and 1986–1997. The results are presented in Table S7. For the 1960–1986 period, the covariate matching methods indicate that parcels within 2 km of protected areas established before 1979 experienced about 6% less deforestation than parcels more than 2 km away from protected areas. One estimate (matching with calipers) is significant at the 1% level, and both are significant at the 5% level. Note, however, that the covariate balance on key elements gets worse in this spillover analysis with the extended set of covariates. For the 1986–1997 period, we find no evidence of large spillover effects using the extended set of covariates.

We test for the sensitivity of our pre-1979 spatial spillover results to a potential unmeasured confounding variable (test described in Section S.2.2 above). In Tables S8 and S14, we test for the sensitivity of the estimates in Tables S7 and S13 respectively. Table S14 indicates that the first row estimate in Table S13 (the only sizeable and significant matching estimate) does *not* remain significantly different from zero in the presence of small unobserved bias. If an unobserved covariate caused the odds ratio of protection to differ between protected and unprotected plots by a factor of 1.1, the 99% confidence interval for that estimate would include zero. In Table S8, the corresponding test for the estimate from the spillover analysis with the extended covariate set (first row of Table S7) also yields a similar conclusion. These sensitivity tests indicate that the sizeable spillover effects detected in Table S7 and S13 are not robust to small amounts of unobserved hidden bias.

Thus, our results suggest that spatial spillovers from protected areas are either absent or positive but small. Given that we estimated small treatment effects of protected areas, the lack of evidence for *negative* spillover effects from protection is not surprising. Our selection models and balancing results suggest that there would be low deforestation pressure on protected lands, implying that protection would lead to little or no displacement of deforestation pressure onto neighboring unprotected lands.

S.3.6 Other Robustness Checks. The conclusions in the main text are also robust to changes in the sample composition, the matching specifications, and the scale at which the analysis is conducted. We confirm that the estimated treatment effects are robust to these variations in the analysis. The matching estimates of avoided deforestation from pre-1979 protection always lie between 5% and 22% (core and extended covariate sets) and, for post-1981, they lie between 2% and 9%. Moreover, the matching estimates are always smaller than their corresponding estimates obtained using the conventional estimation methods.

The robustness checks are described briefly below.

- *Include indigenous reserves and wetlands as protected areas:* We estimate treatment effects without excluding indigenous reserves and wetlands from the sample;
- *Exclude protected areas established in 1981–1985 from post-1981 analysis:* To ensure that there is no substantial bias from using a 1986 forest cover baseline for plots protected a few years before the baseline, we estimate the treatment effects of protection on deforestation between 1986 and 1997, using protection between 1986 and 1996 as the treatment instead of protection between 1985 and 1996;
- *Exclude protected areas established in 1981–1984 and re-run the adjusted sample approach to estimate avoided deforestation for the pre-1979 sample.* We estimate the treatment effect for the post-1985 cohort for the 1986–1997 period, adjust the post-1985 cohort, and re-estimate the treatment effect for the pre-1979 cohort using the full sample.
- *Vary the number of nearest neighbors:* We vary the number of nearest neighbors that are matched with treatment plots from 1 to 10.
- *Match without bias-correction:* We compare our matching estimates to matching estimates without Abadie and Imbens' (22) postmatching, bias correction.
- *Match with alternative measures of land use capacities*: We replace our land-use capacity categories with measures of slope and Holdridge Life Zones (23).
- *Matching with other covariate and propensity score methods*. Based on our analysis of covariate balancing, we chose to use nearest-neighbor Mahalanobis covariate matching with and without calipers. However, to test the sensitivity of our estimates to the matching method, we also tried nearest-neighbor inverse weighting covariate matching, nearest-neighbor and kernel propensity score matching, and a genetic algorithm (15) for covariate matching that uses a generalization of the Mahalanobis metric.
- *Changing the scale of the unit of observation*: Rather than estimate a treatment effect for the minimum mappable unit of 3 ha, we instead estimate a treatment effect for administrative units called *distritos* (districts). Thus our outcome variable is a continuous measure of deforestation expressed as a change in the proportion of the distrito's forest cover over the relevant time period. Instead of distance to nearest road, we use a measure of road density per square kilometer. Instead of a dummy variable for each land productivity category, we use the proportion of the distrito in each category of productivity. For the treatment variable, we choose a treatment of "more than 20% of the district under legal protection," and we varied that threshold from 10% to 30%.

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Table S1. Covariate balance, pre-1979 cohort: Extended covariate set

Variable	Mean protect plots	Mean control plots*	Diff in mean value	Mean eQQ diff**	Median eQQ diff**	Max eQQ diff**	Mean eCDF diff†
High productivity land							
Unmatched	0.006	0.204	−0.198	0.198	0.000	1.000	0.099
Matched	0.006	0.006	0.000	0.000	0.000	0.000	0.000
Medium productivity land							
Unmatched	0.021	0.203	−0.182	0.182	0.000	1.000	0.091
Matched	0.021	0.021	0.000	0.000	0.000	0.000	0.000
Medium-low productivity land							
Unmatched	0.073	0.507	−0.434	0.434	0.000	1.000	0.217
Matched	0.073	0.076	−0.003	0.003	0.000	0.000	0.002
Distance to forest edge in 1960, km							
Unmatched	2.916	2.026	0.890	0.955	1.029	5.559	0.144
Matched	2.916	2.315	0.601	0.601	0.536	2.052	0.088
Distance to road in 1969, km							
Unmatched	17.041	15.461	1.580	1.829	1.820	7.947	0.047
Matched	17.041	16.371	0.670	1.265	0.925	7.308	0.027
Distance to city, km							
Unmatched	77.525	80.542	−3.017	17.00	16.807	33.72	0.116
Matched	77.525	78.624	−1.099	2.859	2.861	12.35	0.029
Distance to river and rail transport network, km							
Unmatched	35.762	27.314	8.448	9.691	9.841	14.03	0.152
Matched	35.762	32.428	3.334	3.489	2.634	12.14	0.046
District area, sq km							
Unmatched	587.86	688.60	100.74	147.6	51.049	835.0	0.019
Matched	587.86	589.72	−1.860	32.38	24.166	509.9	0.031
Population density in 1973, persons per sq km							
Unmatched	16.056	18.741	−2.685	6.238	3.356	3180	0.074
Matched	16.056	16.232	−0.176	3.684	2.409	110.5	0.061
Proportion of immigrants in 1973							
Unmatched	0.419	0.479	−0.060	0.080	0.051	0.342	0.070
Matched	0.419	0.414	0.005	0.020	0.012	0.208	0.029
Proportion of adults with secondary education or higher 1973							
Unmatched	0.052	0.054	−0.002	0.006	0.003	0.115	0.006
Matched	0.052	0.052	0.000	0.004	0.002	0.028	0.004
Proportion of households using fuel-wood 1973							
Unmatched	0.768	0.743	0.025	0.049	0.023	0.252	0.071
Matched	0.768	0.756	0.012	0.023	0.019	0.124	0.062

Low productivity land is the omitted category.

*Values for matched controls are weighted means.

**Mean/Median/Maximum Raw eQQ = mean/median/maximum difference in the empirical quantile-quantile plot of treatment and control groups on the scale in which the variable is measured.

†Mean eCDF = mean differences in empirical cumulative distribution functions.

Table S2. Covariate balance, pre-1979 cohort: Extended covariate set (with calipers)

Variable	Mean protect plots	Mean control plots*	Diff in mean value	Mean eQQ diff**	Median eQQ diff**	Max eQQ diff**	Mean eCDF diff[†]
High productivity land							
Unmatched	0.006	0.204	−0.198	0.198	0.000	1.000	0.099
Matched	0.016	0.016	0.000	0.000	0.000	0.000	0.000
Medium productivity land							
Unmatched	0.021	0.203	−0.182	0.182	0.000	1.000	0.091
Matched	0.055	0.055	0.000	0.000	0.000	0.000	0.000
Medium-low productivity land							
Unmatched	0.073	0.507	−0.434	0.434	0.000	1.000	0.217
Matched	0.160	0.160	0.000	0.000	0.000	0.000	0.000
Distance to forest edge in 1960, km							
Unmatched	2.916	2.026	0.890	0.955	1.029	5.559	0.144
Matched	1.945	1.743	0.202	0.213	0.209	0.879	0.062
Distance to road in 1969, km							
Unmatched	17.041	15.461	1.580	1.829	1.820	7.947	0.047
Matched	14.980	14.663	0.317	0.632	0.558	2.876	0.018
Distance to city, km							
Unmatched	77.525	80.542	−3.017	17.00	16.81	33.72	0.116
Matched	80.677	81.874	−1.197	3.020	2.980	8.550	0.039
Distance to river and rail transport network, km							
Unmatched	35.762	27.314	8.448	9.691	9.841	14.03	0.152
Matched	31.137	31.261	−0.124	1.661	1.338	5.030	0.024
District area, sq km							
Unmatched	587.86	688.60	100.74	147.6	51.049	835.0	0.019
Matched	531.74	527.07	4.670	9.576	0.000	73.45	0.015
Population density in 1973, persons per sq km							
Unmatched	16.056	18.741	−2.685	6.238	3.356	3180	0.074
Matched	11.211	12.451	−1.240	1.374	0.954	9.076	0.049
Proportion of immigrants in 1973							
Unmatched	0.419	0.479	−0.060	0.080	0.051	0.342	0.070
Matched	0.437	0.432	0.005	0.007	0.000	0.071	0.011
Proportion of adults with secondary education or higher 1973							
Unmatched	0.052	0.054	−0.002	0.006	0.003	0.115	0.049
Matched	0.040	0.041	−0.001	0.001	0.000	0.010	0.024
Proportion of households using fuel-wood 1973							
Unmatched	0.768	0.743	0.025	0.049	0.023	0.252	0.071
Matched	0.797	0.792	0.005	0.005	0.001	0.082	0.021

Low productivity land is the omitted category.
*Values for matched controls are weighted means.
**Mean/Median/Maximum Raw eQQ = mean/median/maximum difference in the empirical quantile-quantile plot of treatment and control groups on the scale in which the variable is measured.
[†]Mean eCDF = mean differences in empirical cumulative distribution functions.

Table S3. Covariate balance, post-1981 cohort: Extended covariate set

Variable	Mean value protect plots	Mean value control plots*	Diff in mean value	Mean eQQ diff**	Median eQQ diff**	Max eQQ diff**	Mean eCDF diff†
High productivity land							
Unmatched	0.007	0.109	−0.102	0.102	0.000	1.000	0.051
Matched	0.007	0.007	0.000	0.000	0.000	0.000	0.000
Medium productivity land							
Unmatched	0.006	0.183	−0.177	0.178	0.000	1.000	0.089
Matched	0.006	0.006	0.000	0.000	0.000	0.000	0.000
Medium-low productivity land							
Unmatched	0.116	0.562	−0.446	0.446	0.000	1.000	0.223
Matched	0.116	0.136	−0.020	0.019	0.000	0.000	0.010
Distance to forest edge in 1986, km							
Unmatched	3.076	0.492	2.584	2.584	2.132	6.288	0.348
Matched	3.076	2.230	0.846	0.855	0.743	5.073	0.100
Distance to road in 1991, km							
Unmatched	16.76	5.231	11.53	11.53	13.00	19.32	0.340
Matched	16.76	14.64	2.121	2.411	1.949	6.400	0.067
Distance to city, km							
Unmatched	70.69	74.14	−3.453	5.187	4.475	43.18	0.035
Matched	70.69	64.30	6.386	6.735	5.726	19.67	0.078
Distance to river and rail transport network, km							
Unmatched	36.61	27.79	8.812	11.81	10.11	24.65	0.162
Matched	36.61	33.36	3.247	3.653	3.586	15.29	0.078
District area, sq km							
Unmatched	1498	691.59	806.3	806.5	641	1840	0.116
Matched	1498	1324.5	173.4	173.9	21.94	900.7	0.026
Population density in 1984, persons per sq km							
Unmatched	13.98	21.54	−7.555	7.744	7.170	758.9	0.127
Matched	13.98	14.62	−0.640	1.079	0.000	28.30	0.030
Proportion of immigrants in 1984							
Unmatched	0.295	0.375	−0.080	0.091	0.093	0.191	0.169
Matched	0.295	0.297	−0.002	0.009	0.000	0.076	0.018
Proportion of adults with secondary education or higher 1984							
Unmatched	0.105	0.122	−0.017	0.021	0.020	0.098	0.100
Matched	0.105	0.110	−0.005	0.011	0.000	0.102	0.052
Proportion of households using fuel-wood 1984							
Unmatched	0.724	0.730	−0.006	0.060	0.041	0.332	0.095
Matched	0.724	0.729	−0.005	0.023	0.000	0.225	0.030

Low productivity land is the omitted category.
*Values for matched controls are weighted means.
**Mean/Median/Maximum Raw eQQ = mean/median/maximum difference in the empirical quantile-quantile plot of treatment and control groups on the scale in which the variable is measured.
†Mean eCDF = mean differences in empirical cumulative distribution functions.

Table S4. Covariate balance, post-1981 cohort: Extended covariate set (with calipers)

Variable	Mean protect plots	Mean control plots*	Diff in mean value	Mean eQQ diff**	Median eQQ diff**	Max eQQ diff**	Mean eCDF diff†
High productivity land							
Unmatched	0.007	0.109	−0.102	0.102	0.000	1.000	0.051
Matched	0.016	0.016	0.000	0.000	0.000	0.000	0.000
Medium productivity land							
Unmatched	0.006	0.183	−0.177	0.178	0.000	1.000	0.089
Matched	0.021	0.021	0.000	0.000	0.000	0.000	0.000
Medium-low productivity land							
Unmatched	0.116	0.562	−0.446	0.446	0.000	1.000	0.223
Matched	0.373	0.373	0.000	0.000	0.000	0.000	0.000
Distance to forest edge in 1986, km							
Unmatched	3.076	0.492	2.584	2.584	2.132	6.288	0.348
Matched	0.679	0.493	0.186	0.193	0.198	0.560	0.152
Distance to road in 1991, km							
Unmatched	16.76	5.231	11.53	11.53	13.00	19.32	0.340
Matched	8.159	7.741	0.418	0.615	0.516	2.698	0.040
Distance to city, km							
Unmatched	70.69	74.14	−3.453	5.187	4.475	43.18	0.035
Matched	71.26	70.23	1.034	1.867	1.347	8.650	0.015
Distance to river and rail transport network, km							
Unmatched	36.61	27.79	8.812	11.81	10.11	24.65	0.162
Matched	30.63	29.81	0.825	1.685	1.511	5.194	0.028
District area, sq km							
Unmatched	1498	691.59	806.3	806.5	641.0	1840	0.116
Matched	835.8	830.93	4.850	5.561	0.000	85.11	0.009
Population density in 1984, persons per sq km							
Unmatched	13.98	21.54	−7.555	7.744	7.170	758.9	0.127
Matched	19.16	19.42	−0.263	0.475	0.000	4.214	0.017
Proportion of immigrants in 1984							
Unmatched	0.295	0.375	−0.080	0.091	0.093	0.191	0.169
Matched	0.406	0.408	−0.002	0.003	0.000	0.076	0.004
Proportion of adults with secondary education or higher 1984							
Unmatched	0.105	0.122	−0.017	0.021	0.020	0.098	0.100
Matched	0.122	0.122	0.000	0.001	0.000	0.014	0.008
Proportion of households using fuel-wood 1984							
Unmatched	0.724	0.730	−0.006	0.060	0.041	0.332	0.095
Matched	0.701	0.701	0.000	0.003	0.000	0.062	0.006

Low productivity land is the omitted category.
*Values for matched controls are weighted means.
**Mean/Median/Maximum Raw eQQ = mean/median/maximum difference in the empirical quantile-quantile plot of treatment and control groups on the scale in which the variable is measured.
†Mean eCDF = mean differences in empirical cumulative distribution functions.

Table S5. Estimated avoided deforestation as a proportion of forest protected: Extended covariate set

	Protected before 1979 (control: never protected and forested in 1960)	Protected after 1981 (control: never protected and forested in 1986)
Matching approaches		
Covariate matching†	−0.070* (0.034)	−0.020** (0.033)
[N matched controls]	[527]	[403]
Covariate matching with calipers	−0.146 (0.013)	−0.049 (0.007)
[N outside calipers]	[1757]	[1375]
{N matched controls with calipers}	{397}	{285}
Conventional conservation science approaches		
Difference in means (DIM)‡	−0.438	−0.083
DIM: Controls within 10 km of protected area	−.0375	−0.131
[N available controls]	[3866]	[302]
DIM: Controls within 10 km of PA, include plots deforested preprotection	−0.497	−0.518
{N protected plots}	{1996}	{1494}
[N available controls]	[4956]	[603]
Baseline reference estimate	−0.522	−0.193
N protected plots	2711	2022
N available controls	(10371)	(4716)

*, $P < 0.05$; **, $P > 0.10$; all other coefficients significant at $P < 0.01$.

†Standard errors for post-matching estimates, using the variance formula in ref. 22, are in parentheses next to the estimates.

‡A Chi-squared test is used to evaluate the difference in means.

Table S6. Sensitivity tests to hidden bias: avoided deforestation caliper estimates in Table S5

Γ	Protected pre-1979 (control: never protected and forested in 1960)	Protected post-1981 (control: never protected and forested in 1986)
Critical *P* values for treatment effects*		
1.75	<0.001	<0.001
2.00	<0.001	0.002
2.25	<0.001	0.010
2.50	0.010	0.028
2.75	0.100	0.086
Lower bound 99% confidence interval		
1	−0.272	−0.068
1.5	−0.303	−0.074
2	−0.313	−0.081
2.5	−0.325	−0.091
3	−0.342	−0.097
3.5	−0.358	−0.101
4	−0.385	−0.104

*Test of the null of zero effect.

Table S7. Spatial spillovers: Extended covariate set

	Deforestation 1986	Deforestation 1997
	Unprotected units within 2 km of pre-1979 protected areas (unprotected units more than 2 km away from pre-1979 protected areas)	Unprotected units within 2 km of post-1981 protected areas (unprotected units more than 2 km away from post-1981 protected areas)
Covariate matching[†]	−0.062* (0.025)	0.003** (0.024)
Covariate matching with calipers	−0.056 (0.020)	0.005 (0.018)
[N outside calipers]	[290]	[167]
Difference in means[‡]	−0.168	−0.017**
N treated	1060	556
N available controls	(9849)	(4160)

*, $P < 0.05$; **, $P > 0.10$; All other coefficients significant at $P < 0.01$.
[†]Standard errors for post-matching estimates, using the variance formula in ref. 22, are in parentheses next to the estimates.
[‡]A Chi-squared test is used to evaluate the difference in means.

Table S8. Sensitivity tests to hidden bias: Spatial spillover estimates in Table S7

Γ	Deforestation 1986: Unprotected units within 2 km of pre-1979 protected areas (unprotected units more than 2 km away from pre-1979 protected areas)
Critical p-values for treatment effects*	
1.1	0.692
1.2	0.845

*Test of the null of zero effect.

Table S9. Covariate balance for post-1981 cohort: Core covariate set

Variable	Mean value protect plots	Mean value control plots*	Diff in mean value	Mean eQQ diff**	Median eQQ diff**	Max eQQ diff**	Mean eCDF diff†
High productivity land, proportion							
Unmatched	0.007	0.108	−0.101	0.101	0.000	1.000	0.051
Matched	0.007	0.007	0.000	0.000	0.000	0.000	0.000
Medium productivity land, proportion							
Unmatched	0.006	0.183	−0.177	0.177	0.000	1.000	0.089
Matched	0.006	0.006	0.000	0.000	0.000	0.000	0.000
Medium-low productivity land, proportion							
Unmatched	0.116	0.562	−0.446	0.446	0.000	1.000	0.223
Matched	0.116	0.116	0.000	0.000	0.000	0.000	0.000
Distance to forest edge in 1960, km							
Unmatched	3.076	0.492	2.584	2.584	2.132	6.290	0.348
Matched	3.076	2.461	0.615	0.618	0.356	5.073	0.054
Distance to road in 1969, km							
Unmatched	16.76	5.224	11.54	11.54	13.010	19.33	0.341
Matched	16.76	14.00	2.763	2.766	1.770	8.099	0.070
Distance to city, km							
Unmatched	70.690	74.080	−3.39	5.183	4.377	40.95	0.035
Matched	70.690	69.174	1.516	4.820	3.799	16.83	0.053

Low productivity land is the omitted category.

*Values for matched controls are weighted means.

**Mean/Median/Maximum Raw eQQ = mean/median/maximum difference in the empirical quantile-quantile plot of treatment and control groups on the scale in which the variable is measured.

†Mean eCDF = mean differences in empirical cumulative distribution functions.

Table S10. Covariate balance for pre-1979 cohort: Core covariate set

Variable	Mean value protect plots	Mean value control plots*	Diff in mean value	Mean eQQ diff**	Median eQQ diff**	Max eQQ diff**	Mean eCDF diff†
High productivity land, proportion							
Unmatched	0.006	0.204	−0.198	0.198	0.000	1.000	0.099
Matched	0.006	0.006	0.000	0.000	0.000	0.000	0.000
Medium productivity land, proportion							
Unmatched	0.021	0.203	−0.182	0.182	0.000	1.000	0.091
Matched	0.021	0.021	0.000	0.000	0.000	0.000	0.000
Medium-low productivity land, proportion							
Unmatched	0.073	0.507	−0.434	0.434	0.000	1.000	0.217
Matched	0.073	0.073	0.000	0.000	0.000	0.000	0.000
Distance to forest edge in 1960, km							
Unmatched	2.916	2.026	0.890	0.955	1.029	5.559	0.144
Matched	2.916	2.731	0.203	0.202	0.174	0.764	0.025
Distance to road in 1969, km							
Unmatched	17.041	15.461	1.580	1.829	1.820	7.947	0.047
Matched	17.041	16.134	0.907	1.161	0.428	8.374	0.018
Distance to city, km							
Unmatched	77.525	80.542	−3.017	17.00	16.81	16.81	33.72
Matched	77.525	77.603	−0.078	2.542	2.450	2.450	12.84

Low productivity land is the omitted category.

*Values for matched controls are weighted means.

**Mean/Median/Maximum Raw eQQ = mean/median/maximum difference in the empirical quantile-quantile plot of treatment and control groups on the scale in which the variable is measured.

†Mean eCDF = mean differences in empirical cumulative distribution functions.

Table S11. Covariate balance for pre-1979 cohort: core covariate set (with calipers)

Variable	Mean value protect plots	Mean value control plots*	Diff in mean value	Mean eQQ diff**	Median eQQ diff**	Max eQQ diff**	Mean eCDF diff†
High productivity land, proportion							
Unmatched	0.006	0.204	−0.198	0.198	0.000	1.000	0.099
Matched	0.007	0.007	0.000	0.000	0.000	0.000	0.000
Medium productivity land, proportion							
Unmatched	0.021	0.203	−0.182	0.182	0.000	1.000	0.091
Matched	0.024	0.024	0.000	0.000	0.000	0.000	0.000
Medium-low productivity land, proportion							
Unmatched							
Matched	0.073	0.507	−0.434	0.434	0.000	1.000	0.217
Distance to forest edge in 1960, km	0.083	0.083	0.000	0.000	0.000	0.000	0.000
Unmatched	2.916	2.026	0.890	0.955	1.029	5.559	0.144
Matched	2.557	2.502	0.055	0.078	0.062	0.865	0.014
Distance to road in 1969, km							
Unmatched	17.041	15.461	1.580	1.829	1.820	7.947	0.047
Matched	14.063	13.904	0.159	0.452	0.352	3.095	0.013
Distance to city, km							
Unmatched	77.525	80.542	−3.017	17.00	16.81	33.72	0.116
Matched	67.855	68.307	−0.452	2.157	2.102	13.13	0.025

Low productivity land is the omitted category.

*Values for matched controls are weighted means.

**Mean/Median/Maximum Raw eQQ = mean/median/maximum difference in the empirical quantile-quantile plot of treatment and control groups on the scale in which the variable is measured.

†Mean eCDF = mean differences in empirical cumulative distribution functions.

Table S12. Post-matching regression estimates of avoided deforestation as a proportion of forest protected

	Protected before 1979 (control: never protected and forested in 1960)	Protected after 1981 (control: never protected and forested in 1986)
Regression on core set of covariates*		
Covariate matching	−0.113	−0.031
[N matched controls]	[933]	[681]
Covariate matching with calipers	−0.126	−0.053
[N outside calipers]	[411]	[916]
{N matched controls with calipers}	{924}	{642}
Regression on extended set of covariates (following matching on core set)*		
Covariate matching	−0.126	−0.022
[N matched controls]	[933]	[681]
Covariate matching with calipers	−0.144	−0.047
[N outside calipers]	[411]	[916]
{N matched controls with calipers}	{924}	{642}
N protected parcels	2711	2022
N available controls	(10371)	(4724)

*Only estimated marginal effects are reported.

Table S13. Spatial spillovers: Core covariate set

	Deforestation 1986	Deforestation 1997
	Unprotected units within 2 km of pre-1979 protected areas (unprotected units more than 2 km away from pre-1979 protected areas)	Unprotected units within 2 km of post-1981 protected areas (unprotected units more than 2 km away from post-1981 protected areas)
Covariate matching†	−0.043* (0.022)	0.016** (0.020)
Covariate matching with calipers	−0.045*** (0.020)	0.017** (0.018)
[N outside calipers]	[53]	[43]
Difference in means‡	−0.168	−0.017**
N treated	1060	556
N available controls	(9849)	(4168)

*, $P < 0.10$; **, $P > 0.10$; ***, $P < 0.05$; all other coefficients significant at $P < 0.01$.
†Standard errors for post-matching estimates, using the variance formula in ref. 22, are in parentheses next to the estimates.
‡A Chi-squared test is used to evaluate the difference in means.

Table S14. Sensitivity tests to hidden bias: Spatial spillover estimates in Table S13

Γ	Deforestation 1986: Unprotected units within 2 km of pre-1979 protected areas (unprotected units more than 2 km away from pre-1979 protected areas)
Critical p-values for treatment effects*	
1.1	0.030
1.2	0.262

*Test of the null of zero effect.

Table S15. Covariate balance for post-1981 cohort: Core covariate set (with calipers)

Variable	Mean value protect plots	Mean value control plots*	Diff in mean value	Mean eQQ diff**	Median eQQ diff**	Max eQQ diff**	Mean eCDF diff†
High productivity land, proportion							
Unmatched	0.007	0.108	−0.101	0.101	0.000	1.000	0.051
Matched	0.013	0.013	0.000	0.000	0.000	0.000	0.000
Medium productivity land, proportion							
Unmatched	0.006	0.183	−0.177	0.177	0.000	1.000	0.089
Matched	0.011	0.011	0.000	0.000	0.000	0.000	0.000
Medium-low productivity land, proportion							
Unmatched	0.116	0.562	−0.446	0.446	0.000	1.000	0.223
Matched	0.212	0.212	0.000	0.000	0.000	0.000	0.000
Distance to forest edge in 1986, km							
Unmatched	3.076	0.492	2.584	2.584	2.132	6.290	0.348
Matched	1.304	1.167	0.137	0.139	0.111	0.585	0.051
Distance to road in 1991, km							
Unmatched	16.760	5.224	11.536	11.54	13.010	19.33	0.341
Matched	10.423	9.908	0.515	0.602	0.398	3.249	0.022
Distance to city, km							
Unmatched	70.690	74.080	−3.39	5.183	4.377	40.95	0.035
Matched	70.644	70.805	−0.161	2.206	1.510	9.984	0.019

Low productivity land is the omitted category.

*Values for matched controls are weighted means.

**Mean/Median/Maximum Raw eQQ = mean/median/maximum difference in the empirical quantile-quantile plot of treatment and control groups on the scale in which the variable is measured.

†Mean eCDF = mean differences in empirical cumulative distribution functions.

Table S16. Summary statistics

Name	Description	Mean	Standard dev.	Range
Deforestation 1960–1997	Coded 1 if forest was cleared between 1960 and 1997, 0 otherwise	0.374	0.484	0–1
Deforestation 1960–1986	Coded 1 if forest was cleared between 1960 and 1986, 0 otherwise	0.369	0.483	0–1
Deforestation 1986–1997	Coded 1 if forest was cleared between 1986 and 1997, 0 otherwise (units under forest in 1986 only)	0.084	0.277	0–1
Protection before 1979	Coded 1 if parcel is in a protected area created before 1979, 0 otherwise	0.171	0.377	0–1
Protection 1981–1996	Coded 1 if parcel is in a protected area created between 1981 and 1996, 0 otherwise	0.146	0.353	0–1
Distance to edge of forest 1960	Distance to closest clearing in 1960, measured in km	2.550	2.616	$7.7 \times 10^{-5} - 17.675$
Distance to edge of forest 1986	Distance to closest clearing in 1986, measured in km (units under forest in 1986 only)	11.515	1.293	0.042–12.358
Distance to road 1969	Distance to nearest road in 1969, measured in km	18.260	12.935	0.004–63.641
Distance to railroads and river transportation 1969	Distance to nearest railroad or river transportation in 1969, measured in km	28.367	21.623	0.001–103.70
Distance to local road 1991	Distance to nearest local road in 1991, measured in km	5.026	5.354	$4.8 \times 10^{-4} - 38.719$
Distance to national road 1991	Distance to nearest national road in 1991, measured in km	7.381	7.084	$2.3 \times 10^{-4} - 38.527$
Distance to major city	Distance to closest major city (Limon, Puntarenas, or San Jose), measured in km	78.346	38.778	4.595–212.277
Land use capacity classes:	Dummy variables coded 1 if plot is inside a land class or classes, and 0 otherwise.			
Class I	Agricultural production — annual crops	0.001	0.026	0–1
Class II	Suitable for agricultural production requiring special land and crop management practices such as water conservation, fertilization, irrigation, etc.	0.033	0.179	0–1
Class III	Suitable for agricultural production requiring special land and crop management practices such as water conservation, fertilization, irrigation, etc.	0.088	0.283	0–1
Class IV	Moderately suitable for agricultural production; permanent or semi-permanent crops such as fruit trees, sugar cane, coffee, ornamental plants, etc.	0.125	0.330	0–1
Class V	Strong limitations for agriculture; forestry or pastureland	0.016	0.127	0–1
Class VI	Strong limiting factors on agricultural production; land is only suitable for forest plantations or natural forest management	0.169	0.375	0–1
Class VII	Strong limiting factors on agricultural production; land is only suitable for forest plantations or natural forest management	0.151	0.358	0–1
Class VIII	Land is suitable only for watershed protection	0.031	0.173	0–1
Class IX	Land is suitable only for protection	0.385	0.487	0–1
District area	Area of district in which land plot is located, measured in square km	834.000	710.000	2.161–2410.000
Census variables 1973				
Population density	Population density of district in which land plot is located, measured as number of people per square km	15.638	53.906	0.886–3671.928
Percentage of immigrants	Number of people born outside their canton of residence	0.458	0.221	0.014–0.913
Percentage of adults with secondary-level education	Percentage of adults with secundaria or universitaria level education	0.055	0.051	0.007–0.335
Fuel-wood use	Percentage of households using fuel-wood for cooking	0.740	0.254	0.088–0.994
Census variables 1984				
Population density	Population density of district in which land plot is located, measured as number of people per square km	20.764	64.849	0.779–4008.375
Percentage of immigrants	Percentage of people born outside their canton of residence	0.389	0.165	0.050–0.734
Percentage of adults with secondary-level education	Percentage of adults with secundaria or universitaria level education	0.113	0.077	0.002–0.458
Fuel-wood use	Percentage of households using fuel-wood for cooking	0.733	0.213	0.047–0.996